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BIOLOGICAL CHARACTERISTICS OF GREAT LAKES ALEWIFE, *ALOSA PSEUDOHARENGUS*: IMPLICATIONS FOR THE EFFECTS OF IMPINGEMENT

David W. Rodgers
Research Division, Ontario Hydro

Peter E. Ihssen and G. William Martin
Ontario Ministry of Natural Resources

Report No 89-125-K

ABSTRACT

At Pickering NGS, impinged alewife were generally similar to open lake fish. The differences which were observed between impinged and open water fish likely resulted from the stresses of continuous swimming against the intake current and possible food deprivation. Allelic frequencies of 25 protein coding loci in Great Lakes alewife were uniform with no significant differences in allelic frequency among locations. Alewife from Maritime Canada were distinct from Great Lakes alewife with significant differences in allelic frequency at five of the eight polymorphic loci (*Ak*, *Gpi*, *Idh-2*, *Ldh-2* and *Mpi*). Maritime alewife also differed significantly among locations (*Ak* and *Mpi*). The electrophoretic and meristic uniformity among Great Lakes alewife signifies that alewife in Lake Ontario likely originated from a single invasion or single source and have yet to differentiate into distinct stocks. Further, the invasion by alewife of the upper Great Lakes apparently was not accompanied by a population bottleneck and the accompanying loss of genetic variability. This implies either that a relatively large population of alewife invaded the upper Great Lakes originally or that continuous invasions have maintained genetic integrity. As Great Lakes alewife were genetically uniform and allelic frequencies did not differ significantly between impinged and open water fish at Pickering NGS "A", impingement would not be expected to affect the genetic composition of Great Lakes alewife.

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EXECUTIVE SUMMARY
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David W. Rodgers
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Following their introduction, alewife have proliferated within the Great Lakes, especially Lakes Ontario and Michigan. In these lakes, alewife are the principal prey consumed by the many salmonine species, which form the basis for a substantial sport fishery (Brandt 1986; Jude et al. 1987). Because of their abundance, alewife may also affect the operations of industries, such as Ontario Hydro, which pass large volumes of waters from the Great Lakes through their cooling water systems. The average loss of adult alewife from Lake Ontario through impingement by Ontario Hydro facilities is estimated at approximately 140,000 kg per year (Christie and Wismer in press) but in some years, more than 200,000 kg of alewife have been impinged at Pickering Nuclear Generating Station (NGS) "A" alone. In extreme events, the reduction in cooling water flow caused by alewife impingement may affect station operations. Even when fish impingement does not significantly affect station operation, however, the loss of fish through impingement may have ecological implications and economic costs.

A major limitation to the assessment of the significance of fish impingement has been the scarcity of information concerning the biological characteristics of impinged fish; knowledge which may be critical to the meaningful assessment of the ecological effects of fish impingement. Information concerning the genetic structure of Great Lakes alewife is required for management decisions concerning the population effects of local events such as fish impingement. Comparisons of open water and impinged fish would provide a perspective to evaluate whether impinged alewife are representative of the open lake fish or if impingement selects diseased or unhealthy fish.

The present studies investigated some of the biological characteristics of alewife from Lakes Ontario and Huron. The genetic structure among Great Lakes alewife and additional alewife collected from the Maritime provinces was determined by comparing allelic frequencies of twenty-five protein-coding loci which were quantified using electrophoretic techniques. For Great Lakes alewife, several morphological characteristics (measurements of body parts) and meristic parameters (counts of hard bony structures such as fin rays) were also determined.

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Additional alewife were collected from the cooling water intake of Pickering NGS and the adjacent open lake to evaluate their pathological and parasitological condition.

At Pickering, impinged alewife were generally similar to open lake fish. The differences which were observed between impinged and open water fish were likely the result of the stress of food deprivation and continuous swimming against the intake current. Consequently, alewife impingement at Pickering NGS does not appear to select sick or diseased fish.

Allelic frequencies of Great Lakes alewife did not differ significantly among locations. In contrast, Maritime alewife were distinct from Great Lakes alewife and also differed significantly among Maritime collection sites. The genetic integrity of Great Lakes alewife signifies that alewife in Lake Ontario likely originated from a single invasion or single source and have yet to differentiate into distinct stocks. Electrophoretic analysis of alewife from the upper St. Lawrence River and the waters supplying the Erie Canal system may be of considerable use in resolving the origin of Lake Ontario alewife. The consistency between Lake Huron and Lake Ontario alewife indicates that the invasion by alewife of the upper Great Lakes apparently was not accompanied by a population bottleneck and the accompanying loss of genetic variability. This implies either that a relatively large population of alewife invaded the upper Great Lakes originally or that continuous invasions have maintained genetic integrity. As Great Lakes alewife were genetically uniform and allelic frequencies did not differ significantly between impinged and open water fish at Pickering NGS "A", impingement would not be expected to affect the genetic composition of Great Lakes alewife.

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TO: Dr. D. Mills
Director of Research

BIOLOGICAL CHARACTERISTICS OF GREAT LAKES ALEWIFE, *ALOSA PSEUDOHARENGUS*: IMPLICATIONS FOR THE EFFECTS OF IMPINGEMENT

1.0 INTRODUCTION

Alewife, *Alosa pseudoharengus*, were reported in Lake Ontario as early as 1873, although their origin has yet to be definitively established (Scott and Crossman 1973). Alewife most probably colonized Lake Ontario by way of the Erie Barge Canal system (Smith 1970) but they may also have entered Lake Ontario by ascending the St. Lawrence River or through accidental inclusion in a planting of American shad, *Alosa sapidissima*, into Lake Ontario in the 1870's. Alternatively, alewife may have been present in Lake Ontario since the invasion of the Champlain Sea (Scott and Crossman 1973). Alewife in the upper Great Lakes are presumed to have originated in Lake Ontario and entered Lake Erie by way of the Welland Canal or the Erie Barge Canal. They were first reported in Lake Erie in the early 1930's and spread to the other Great Lakes in the next decades (Scott and Crossman 1973).

Following their introduction, alewife have proliferated within the Great Lakes, especially Lakes Ontario and Michigan. In these lakes, alewife are the principal prey consumed by the many salmonine species which form the basis for a substantial sport fishery (Brandt 1986; Jude et al. 1987). The central role of alewife in the Great Lakes has been recognized in several recent studies including an evaluation of the influences of alewife on species interactions in Lake Michigan (Crowder 1986); a model of consumption and food conversion by alewife in Lake Michigan (Stewart and Binkowski 1986), and a detailed examination of the abundance and growth of alewife in the U.S. waters of Lake Ontario following a severe winter mortality in 1976 (O'Gorman and Schneider 1986).

Because of their abundance and behaviour, alewife may also affect the operations of industries, such as Ontario Hydro, which pass large volumes of water from the Great Lakes through their cooling water systems. The average loss of adult alewife from Lake Ontario through impingement at Ontario Hydro facilities is estimated at approximately 140,000 kg per year (Christie and Wismer in press) but in some years, more than 200,000 kg of alewife have been impinged at Pickering Nuclear Generating Station (NGS) "A" alone. In extreme events, the reduction in cooling water flow caused by alewife impingement may affect station operations. Even when fish impingement does not significantly affect station operation, however, the loss of fish through impingement may have ecological implications and economic costs. A major limitation to the assessment of the significance of fish impingement is the paucity of information concerning the biological characteristics of impinged fish; information which may be critical to the meaningful

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assessment of the ecological effects of fish impingement. Unfortunately, although inventories of fish impingement at Ontario Hydro generating stations on the Great Lakes are routinely available (ie Ontario Hydro 1984 - RMEP-IR-07000-11), they do not go beyond estimates of the species, numbers and weight of fish impinged. Fish impinged at generating stations are often considered to be unhealthy (Foster and Wheaton 1981), but the differences between impinged fish and those in open lake have not been rigorously documented. Similarly, the genetic aspects of population structure of Great Lakes alewife have yet to be assessed. Genetic information may be required to assess the impact on the population, of local events, such as impingement, pollution or disease.

In the present studies, we investigated some of the basic biological characteristics of alewife from Lakes Ontario and Huron. The genetic structure among Great Lakes alewife and additional alewife collected from the Maritime provinces was determined by comparing allelic frequencies of more than twenty protein-coding loci. Several morphological and meristic characteristics of Great Lakes alewife were also examined. At Pickering Nuclear Generating Station (NGS) "A", the pathological and parasitological characteristics of alewife impinged in the cooling water intake were compared with those of fish collected from the open lake. These studies thus provide a basis for evaluation of the genetic structure of Great Lakes alewife and comparing the condition of open water and impinged fish.

2.0 MATERIALS AND METHODS

2.1 Collection of Fish

Great Lakes alewife were collected at three locations on Lake Ontario (Cobourg, Pickering and Grimsby), from the Niagara River at Queenston (slightly upstream of mouth of the river to Lake Ontario), and from two locations on Lake Huron (Bruce NGS "A" and South Bay) (Figure 1). Alewife were collected using seine or dip nets. At Pickering, both impinged and open water fish were collected. Impinged alewife were collected from within the screenwells at the cooling water intake of Pickering NGS "A", while the open water alewife were collected from Lake Ontario at a beach approximately 1 km east of the Pickering NGS "A". In the Lake Ontario and the Niagara River collections, adult alewife, with a total length greater than 100 mm, were selected. The fish were collected from June 10-25, 1986, which corresponds to their spawning period. At Bruce NGS, young-of-the-year fish were collected on September 16, 1986, as we were unable to collect adult alewife at the site. Adult alewife from South Bay were collected in 2.5 to 4 cm gill nets by Ontario Ministry of Natural Resources personnel on July 14, 1987.

In each collection, approximately 65 fish were transported alive to the laboratory (MNR - Maple, Ontario) for electrophoretic analysis of allelic frequencies and 50 fish were preserved in 5% formalin for meristic and morphological analysis. In each of the Pickering collections, an additional 25 fish were collected for pathological and parasitological analysis. These fish were preserved in phosphate buffered formalin (Roberts 1978) after dissection of the right body wall. Fish collected from South Bay were frozen on dry ice immediately following capture and processed for electrophoretic analysis within three days.

Maritime alewife were collected from the Gaspereau River, Nova Scotia, and at the Mactaquac Dam on the St. John River, New Brunswick in the June, 1987, and from the Miramichi River, Millbank, New Brunswick in June 1988. Approximately 75 fish from each location were captured in trap nets supervised by the Department of Fisheries and Oceans. The fish were frozen on dry ice and transported by air to Toronto, from whence they were transferred to the lab at Maple for electrophoretic analysis.

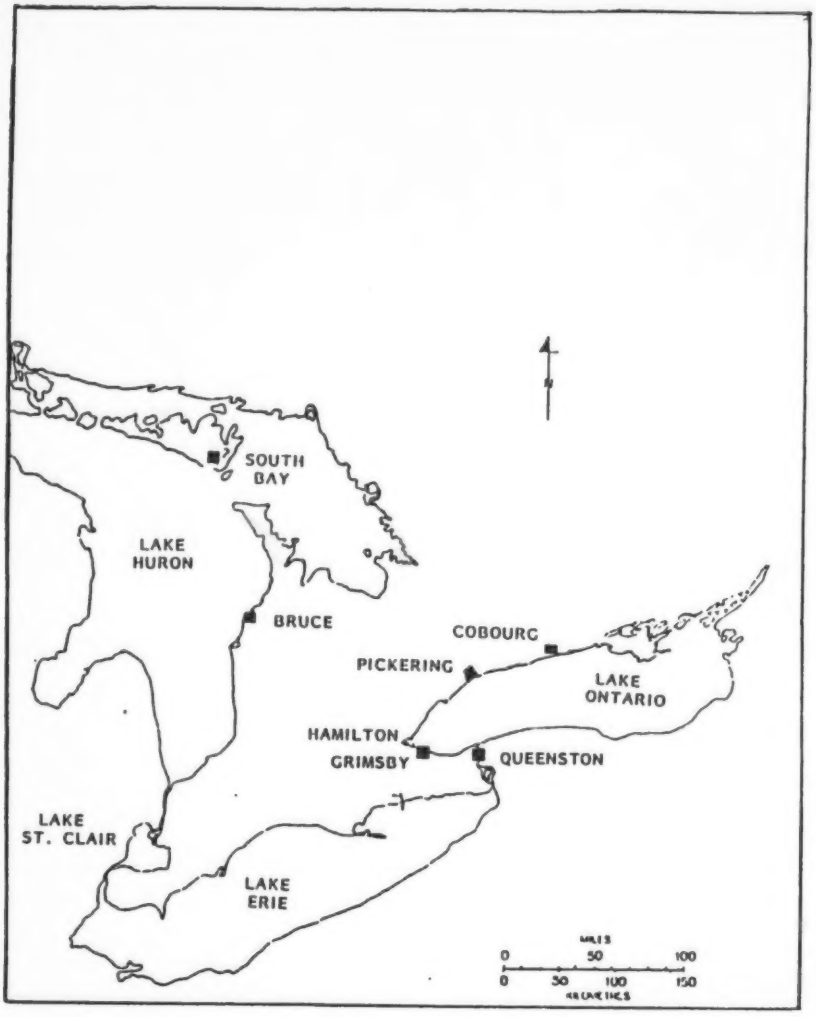

FIGURE 1

GREAT LAKES SAMPLING LOCATIONS

2.2 Electrophoretic Analysis

The methods used to analyze the twenty-five protein coding loci listed in Table 1 have been previously described in detail (Casselman et al. 1981). With liver *Sdh*, consistent electrophoretic results were only obtained with Great Lakes alewife and this system could not be assayed for the frozen Maritime samples. Differences in allelic frequency were determined using the Fisher exact probability test with a significance level of $P < 0.05$.

2.3 Meristic Characters and Morphological Measurements

The formalin preserved Great Lakes alewife were kept for at least three months to allow size and weight changes to stabilize before meristic characters and morphological characteristics were measured. Meristic characters counted were the principal fin rays in the anal, dorsal and pectoral fins. The morphometric characters measured were total length, standard length, head length, orbit diameter and Midbody depth which were measured as the greatest vertical distance from the anterior insertion of the dorsal fin (MacCrimmon et al. 1983). In addition, fish collected at Pickering (impinged and open water) were weighed after blotting dry with a paper towel. The fish were then dissected, sexed, and the liver and gonad were removed and weighed.

The relationships of meristic and morphological characteristics among Great Lakes collection sites were examined using canonical discriminant analysis (SAS 1987). For Pickering alewife, the relationships of length and weight of impinged and open water fish were compared using dummy variable regression techniques (Kleinbaum and Kupper 1978). Liver and gonad weights of impinged and open water alewife at Pickering were contrasted using an analysis of variance with weight as a covariate (Steel and Torrie 1980). The logarithmic transformation was employed when examination of residual and normal probability plots indicated that this transformation was required to comply with statistical assumptions of normality and equivalence of variance. In all statistical tests, differences between groups were considered significant if $P \leq 0.05$.

2.4 Pathological Analysis

Pathological analysis was conducted by Dr. B. Hicks, Department of Pathology, University of Guelph. Fish preserved in phosphate buffered formalin were dissected and spleen, liver, kidney, intestine, gonad, heart, muscle, gill, brain, eye and skin tissues processed for routine histopathological examination. Preparations from these tissues were examined under a light microscope and pathological changes recorded and compared between impinged and open water fish.

3.0 RESULTS AND DISCUSSION

Great Lakes alewife appear to be derived from a single panmictic population. Although alewife were polymorphic at eight of the twenty-five protein coding loci examined (*Ak, Ck-2, Gpi, Idh-1, Idh-2, Ldh-2, Mpi* and *Sdh*), allelic frequencies of Great Lakes alewife did not differ significantly among locations (Table 2). In contrast, Maritime alewife were distinct from Great Lakes alewife, with significant differences in allelic frequency at five loci (*Ak, Gpi, Idh-2, Ldh-2* and *Mpi*). Maritime alewife also differed significantly among locations (*Ak* and *Mpi*). For the combined Great Lakes samples, observed allelic frequencies of each polymorphic locus did not depart significantly from Hardy-Weinberg equilibrium. In addition, allelic frequencies did not deviate significantly from Hardy-Weinberg equilibrium in 12 of the 13 individual combinations of loci and location for which the test could be meaningfully applied. The exception was *Sdh* at Grimsby, however, *Mpi* at the same location did not significantly diverge from Hardy-Weinberg equilibrium.

TABLE 1. Protein-coding loci, their Enzyme Commission (EC) numbers (International Union of Biochemistry 1984) and the tissues and buffers in which they were resolved. A complete description of the buffer systems is contained in Casselman et al. (1981).

Enzyme, protein	EC no.	Locus	Buffer System	Tissue	Variant alleles
Asparate aminotransferase	2.6.1.1	Aat	A	Muscle	none
Aldolase	4.1.2.13	Ald	B	Muscle	none
Adenylate kinase	2.7.4.3	Ak	D	Muscle	53,145
Creatine kinase	2.7.3.2	Ck-2	A	Muscle	138
Cathodal muscle protein	-	Cmp	A	Muscle	none
Glycerol-3-phosphate dehydrogenase	1.1.1.8	G3P	B	Muscle	none
B-Galactose aminidase	-	Gam	A	Liver	none
Glyceraldehyde-phosphate dehydrogenase	1.2.1.12	Gap-1	B	Muscle	none
		Gap-2	B	Muscle	none
General muscle protein	-	Gmp	B	Muscle	none
Glucosephosphate isomerase	5.3.1.9	Gpi	A	Muscle	170
Isocitrate dehydrogenase	1.1.1.42	Idh-1	D	Muscle	150
		Idh-2		Liver	92
Lactate dehydrogenase	1.1.1.27	Ldh-2	A	Muscle	79,87
Malate dehydrogenase	1.1.1.37	Mdh-1	B	Muscle	none
		Mdh-2		Muscle	none
		Mdh-3		Muscle	none
Malic enzyme	1.1.1.40	Me-1	D	Muscle	97
		Me-2		Liver	none
Mannose phosphate isomerase	5.3.1.8	Mpi	B	Heart	121
4-Methylumbelliferyl phosphatase	3.1.3.2	Mup	B	Liver	none
Phosphogluconate dehydrogenase	1.1.1.44	Pgd	B	Muscle	90
Phosphoglucomutase	2.7.5.1	Pgm-1	B	Muscle	none
Sorbitol dehydrogenase	1.1.1.14	Sdh	A	Liver	125
Superoxide dismutase	1.15.1.1	Sod	A	Liver	76

TABLE 2. Allelic frequencies of polymophic loci of alewife.
Only the frequencies of the less common alleles at each locus are given.
(The number of fish examined at each site is given in parentheses.)

Location	Gpi^{170}	$Idh\text{-}2^{92}$	$Ldh\text{-}2^{a}$	Mpi^{121}	Sdh^{92}
Cobourg (69)	0.000	0.000	0.014	0.362	0.196
Pickering Intake (63)	0.008	0.000	0.008	-	0.214
Pickering Open Lake (72)	0.014[b]	0.000	0.021	0.326	0.181
Grimbsy (72)	0.007	0.000	0.014	0.319	0.167
Queenston (75)	0.020	0.000	0.013	0.365	0.173
Bruce (72)	0.007	0.000	0.014	0.306	0.160
South Bay (80)	0.013	0.000	0.013	0.306	0.194
Great Lakes (503)	0.010	0.000	0.014	0.330	0.183
Miramichi River (100)	0.000	0.000	0.000	0.890	-
St. John River Mactaqac (74)	0.000	0.014	0.000	0.649	-
Gaspereau River (74)	0.000	0.053	0.000	0.513	-

Rare alleles: Gaspereau River Ak^{145} (0.060), Sod^{76} (0.020); Grimbsy Idh^{150} (0.007); Miramichi Ak^{53} (0.005), Ak^{145} (0.005), $Me\text{-}1^{97}$ (0.010), Pgd^{90} (0.008); South Bay $Ck\text{-}2^{138}$ (0.013).

[a] combined frequency of $Ldh\text{-}2^{79}$ and $Ldh\text{-}2^{87}$ alleles which were not differentiated in some samples.
[b] N=36.

In canonical discriminant analysis of the morphometric and meristic characters of the Great Lakes alewife (Table 3), the first canonical variable largely reflected the differences in the average size of fish collected from the different locations. Ordination along the second and third canonical variables revealed statistically significant differences in the "shape" of fish among locations (Figure 2). In this analysis, morphological measurements were the important variables separation among locations, while the meristic variables were relatively unimportant. Ihssen et al. (1981) noted that in lake whitefish, *Coregonus clupeaformis*, the order of separation observed in analyses using electrophoretic variation was complementary to that obtained using meristic characters, but a different pattern of separation was obtained from analyses based on morphometric parameters. They concluded that variation in morphometric parameters was sensitive to local environmental factors, particularly growth rate, but that variation in meristic characters was largely determined by genotype. As the uniformity of meristic characters in Great Lakes alewife was consistent with the genetic homogeneity deduced from the electrophoretic analysis, the observed differences in morphometric parameters also likely reflected variation in local environmental factors rather than genetic differences.

The electrophoretic and meristic uniformity among Great Lakes alewife signifies that alewife in Lake Ontario likely originated from a single invasion or single source and have not differentiated into distinct stocks. Further, the consistency between Lake Huron and Lake Ontario alewife indicates that the invasion by alewife of the upper Great Lakes apparently was not accompanied by a population bottleneck and the accompanying loss of genetic variability. This implies either that a relatively large population of alewife invaded the upper Great Lakes originally or that continuous invasions have maintained genetic integrity.

Great Lakes alewife were genetically more similar than sympatric and allopatric stocks of native fish from the Great Lakes (e.g. Ihssen et al. 1988). Among other fish introduced to the Great Lakes within the last century, the degree of genetic differentiation observed has varied. Pink salmon, *Oncorhynchus gorbuscha*, were genetically uniform throughout the Great Lakes (Gharrett and Thomason 1987), but differed significantly from the original anadromous population from which they were derived. MacCrimmon et al. (1983) in an analysis of meristic, morphometric and electrophoretic characteristics of rainbow smelt, *Osmerus mordax*, in Lake Erie, were unable to demonstrate statistical evidence of genetic differences among samples, although growth rates differed significantly between basins. In contrast, Schreiner et al. (1984) reported significant differences in allelic frequencies at the serum transferring (*Tfn*) locus among sympatric stocks of rainbow smelt in Lake Superior. These genetic differences were consistent with observed differences in the length-frequency distributions, fecundity and growth (Luey and Adelman 1984). Statistically significant differences in allelic frequencies were observed for naturalized populations of brown trout, *Salmo trutta*, and rainbow trout, *Salmo gairdneri*, in Lake Superior (Krueger and May 1987a, b), although the level of population differentiation was less than that reported for native populations.

In contrast to Great Lakes alewife, Maritime alewife appear to have differentiated into stocks which were distinct from Great Lakes alewife and among Maritime collection sites. As with Great Lakes alewife, there are relatively few comparable studies of Atlantic alewife. McKenzie (1973) was unable to distinguish differences in electrophoretic patterns of LDH or muscle myogen among alewife from Coventry Bay, Prince Edward Island and three locations on the St. John River New Brunswick, although there were distinct differences in muscle myogen patterns between alewife and blueback herring, *Alosa aestivalis*. Alewife from various locations in the St. John River, N.B. showed differences in morphometric and meristic characters, but there was considerable overlap in the frequency distributions of meristic characters between adjacent areas (Messieh 1977).

TABLE 3. Summary of morphological and meristic characteristics of Great Lakes Alewife (50 fish/location)

		Total Length (mm)	Standard Length (mm)	Head Depth (mm)	Midbody Depth (mm)	Eye Diameter (mm)	Dorsal Rays	Anal Rays	Pectoral Rays
Cobourg	$\bar{X}$	162.7	130.4	35.0	31.0	10.5	14.2	17.2	15.0
	SD	18.1	13.9	4.2	3.3	1.4	0.68	1.02	0.47
	MAY	106	87	21.9	20.5	6.7	13	15	14
	MIN	193	152	43.5	38.2	12.6	16	18	16
Pickering Intake	$\bar{X}$	151.7	121.3	33.1	29.3	10.1	14.1	17.1	14.5
	SD	21.3	16.3	4.7	3.9	1.7	0.59	1.03	0.68
	MIN	97	77	20.3	18.7	5.9	13	14	13
	MAY	188	147	40.4	37.4	12.4	15	19	16
Pickering Open Water	$\bar{X}$	132.2	106.7	28.1	26.6	8.4	14.2	16.8	14.6
	SD	21.1	16	4.9	4.1	1.6	0.64	0.81	0.76
	MIN	102	82	20.4	20.4	6	13	15	13
	MAY	182	144	38.2	36.2	11.3	15	19	17
Grimsby	$\bar{X}$	146.9	118.9	31.2	31.7	9.4	14.1	16.9	14.4
	SD	6.8	5.4	1.5	1.6	1.2	0.75	0.94	0.54
	MIN	132	109	29	28.6	8.3	12	15	14
	MAY	170	137	35.7	36	17	16	19	16
Queenston	$\bar{X}$	150.3	121.6	32.9	31.5	9.7	14	17	14.5
	SD	8.6	6.7	2.0	1.9	0.7	0.59	1.03	0.58
	MIN	135	110	28.8	25	8.7	13	15	13
	MAY	172	139	38.4	35.5	11.8	15	19	15
Bruce	$\bar{X}$	61.6	51.1	13	12.4	4	14.4	16.6	14.3
	SD	10.6	8.7	2.2	2.5	0.7	1.09	1.1	0.6
	MIN	40	33	8.7	7.3	2.8	11	15	13
	MAY	78	65	17.4	16.8	5	16	19	16

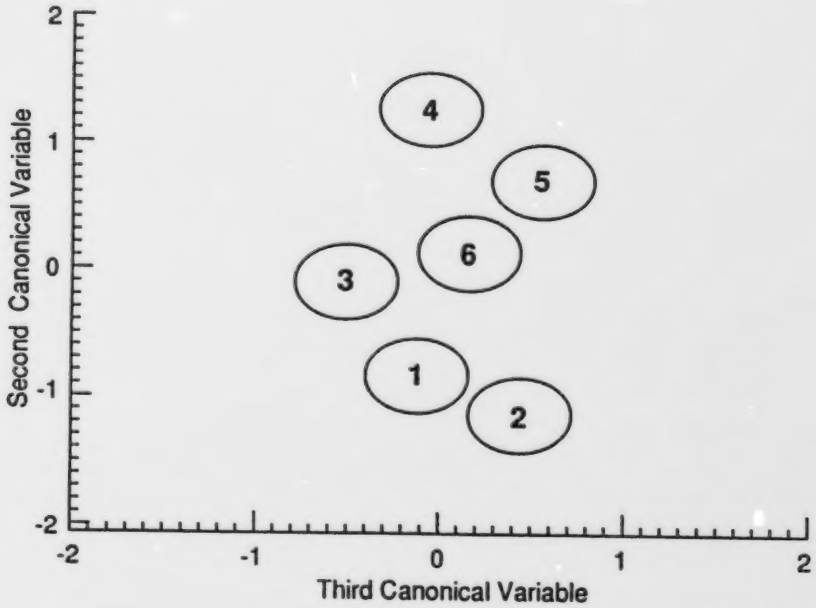

FIGURE 2

SEPARATION OF GREAT LAKES ALEWIFE USING CANONICAL DISCRIMINANT ANALYSIS OF MORPHOLOGICAL AND MERISTIC PARAMETERS. MEAN WITH 95% CONFIDENCE INTERVALS

(1 - COBOURG, 2 - PICKERING INTAKE, 3 - PICKERING OPEN LAKE, 4 - GRIMSBY, 5 - QUEENSTON, 6 - BRUCE)

The differences between Maritime and Great Lakes alewife likely result from differences in both the length of isolation and life history of the alewife populations. Maritime alewife are presumed to have entered their natal rivers following the last glaciation and have thus had thousands of generations for populations to separate into distinct stocks. Alewife are presumably recent invaders of Lake Ontario, although the origin and duration of their isolation has yet to be determined. Electrophoretic analysis of alewife from the upper St. Lawrence River and the waters supplying the Erie Canal system may be of considerable merit in resolving the origin of Lake Ontario alewife. The genetic similarity of Lake Huron and Lake Ontario alewife is consistent with hypothesis that alewife in the upper Great Lakes originated from Lake Ontario (Scott and Crossman 1973).

The contrast between Great Lakes alewife and Maritime alewife may also reflect differences in life history. In general, anadromous maritime alewife return to their natal river to spawn, although there may be some intermingling among populations from different tributaries of the natal river (Thunberg 1971; Messieh 1977). In the Great Lakes alewife spawn on shallow nearshore beaches and homing has not been demonstrated (Scott and Crossman 1973). The beach spawning of Great Lakes alewife would thus contribute to genetic uniformity, while the homing of maritime alewife to natal rivers would lead to genetic separation of the populations.

Neither allelic frequencies nor meristic counts differed significantly between impinged and open water alewife, although impinged alewife were slightly but significantly larger and heavier than open water fish. This difference in size of fish likely reflects sampling variation rather than selection, however, as significant differences in length were also observed among the samples of alewife from other Lake Ontario locations (Table 3). Of greater significance was the fact that impinged fish weighed slightly but significantly less at a given length than open lake fish (Figure 3) and also had a significantly lower liver weight at a given weight. These changes would be expected in fish deprived of food and forced to swim against the intake current for a prolonged period at velocities significantly greater than normal cruising speed (Beamish 1978); conditions which would apply to alewife impinged in the intake forebay. Our observations are also consistent with earlier observations of alewife at Pickering NGS, where Hutcheson (1981) reported a significant increase in lactic acid levels in impinged alewife. In our samples, impingement did not appear to select spent fish, as gonad weight at a given weight did not differ significantly between impinged and open water alewife of either sex.

In general, the health of impinged fish was comparable to that of fish from open water, and the majority of the pathological lesions observed were common to both impinged and open water alewife (Table 4). The gills were the organ most commonly affected (15 of the 32 lesions observed), with lesions ranging from mild multifocal epithelial hyperplasia to severe mycotic branchitis. Many of the gill lesions were associated with specific disease organisms; Nodular Gill Disease, *Costia sp.*, or *Chilodinella sp.* Other lesions observed included; lenticular disomiasis (infestation of the lens of the eye by metacercaria of the fluke, *Diplostomum sp.*.), mild nephrocalcinosis (accumulation of calcium in the kidney tubules), the presence of cestodes in the lumen of the intestine, focal granulomatous hepatitis and mild diffuse epicarditis.

The lesions observed were not considered either extensive or severe enough to be life threatening. All lesions except nephrocalcinosis were likely parasitic in origin. This condition also ran counter to the general pattern observed with other lesions in that it was observed only in impinged alewife (5 of 25 impinged fish, 0 of 25 open water fish). Specific known causes of nephrocalcinosis include imbalances in dietary cation intake and elevated concentrations of carbon dioxide in the water (Roberts 1978), but these conditions would not appear to apply to the intake forebay and impinged alewife. While it is tempting to suggest that the incidence of nephrocalcinosis is in some way related to the stresses of impingement, the condition has been

TABLE 4: Summary of pathological lesions of impinged and open lake alewife at Pickering NGS "A" (25 fish/collection site)

Organ	Lesion	Incidence (%) Impinged	Open Lake
Gill			
	Multifocal epithelial hyperplasia (unknown etiology)	5 (20%)	4 (16%)
	Multifocal epithelial hyperplasia - Chilodinella sp.	1 (4%)	1 (4%)
	Multifocal epithelial hyperplasia - Costia (Ichthyobia)	1 (4%)	-
	Multifocal epithelial hyperplasia - A cells (Nodular Gill Disease)	-	2 (8%)
	Focal mycotic branchitis	-	1 (4%)
Eye			
	Lenticular distomiasis	4 (16%)	2 (8%)
Intestine			
	Intestinal cestodiasis	1 (4%)	2 (8%)
	Multifocal granulomatous peritonitis	-	3 (12%)
Kidney			
	Nephrocalcinosis	5 (20%)	-
Liver			
	Focal granulomatous hepatitis	1 (4%)	-
Heart			
	Mild diffuse epicarditis (bulbar arteriosus)	1 (4%)	-

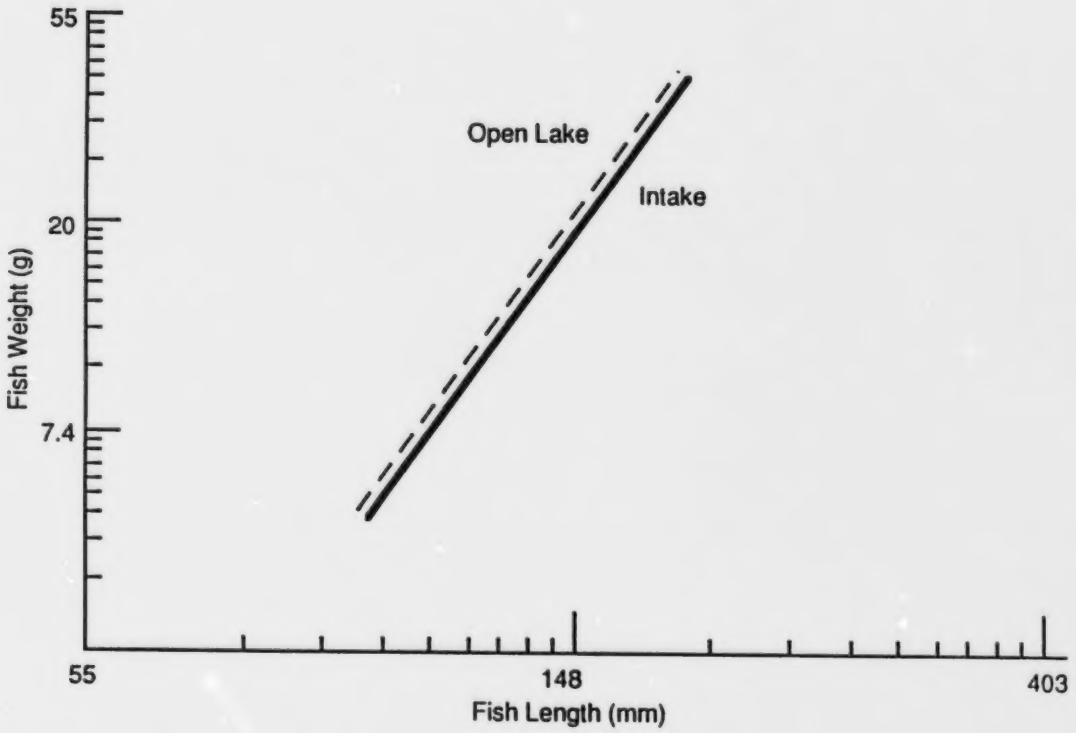

FIGURE 3

LENGTH - WEIGHT RELATIONSHIP OF PICKERING ALEWIFE

(------ OPEN LAKE ALEWIFE, —— INTAKE ALEWIFE)

observed previously in wild fish from Lake Ontario and the present samples were not sufficient for detailed statistical analysis. The gill diseases, Nodular Gill Disease, *Costia sp.*, and *Chilodinella sp.* were notable as these diseases are normally associated with cultured rather than wild fish. However, wild fish are seldom examined in detail. At Nanticoke Thermal Generating Station, on Lake Erie, a higher proportion of apparently unhealthy fish were captured in the intake forebay than in the adjacent open lake (Foster and Wheaton 1981); however, in this study, fish health was only assessed by visual examination of external anatomy.

As impinged alewife were generally similar to open lake fish, impingement at Pickering NGS does not appear to select unhealthy fish. The differences which were observed between impinged and open water fish likely resulted from the stress of continuous swimming against the intake current and possible food deprivation. In addition, impingement would not be expected to affect the genetic composition of Great Lakes alewife as the fish were genetically uniform and allelic frequencies did not differ significantly between impinged and open water fish at Pickering NGS "A".

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Prepared and Submitted by:

D.W. Rodgers
Biologist
Biological Research Section

Prepared by:

P.E. Ihssen and G.W. Martin
Ontario Ministry of Natural Resources

Approved by:

D.J.R. Dodd
Manager
Chemical Research Dept

Reviewed by:

F.S. Spencer
Acting Section Head
Biological Research Section

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